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FINAL REPORT

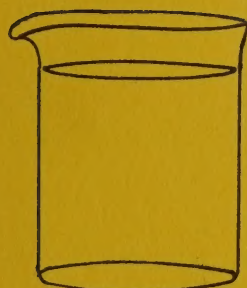
on

CHARACTERIZATION OF SOIL AND GEOLOGIC  
MATERIALS OVERLYING COAL SEAMS  
AS PLANT GROWTH MEDIA

for

LAM CREEK, COLORADO

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Greenhouse



Colorado State University

DEPARTMENT OF AGRONOMY

Soil Survey and Interpretation Research Group

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FINAL REPORT

on

CHARACTERIZATION OF SOIL AND GEOLOGIC  
MATERIALS OVERLYING COAL SEAMS  
AS PLANT GROWTH MEDIA

for

LAY CREEK, COLORADO  
EMRIA STUDY SITE

Submitted to: UNITED STATES DEPARTMENT OF THE INTERIOR  
WATER AND POWER RESOURCES SERVICE

Denver, Colorado

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## INTRODUCTION

This report describes the results of a study conducted for the Water and Power Resources Service to characterize soil and geological overburden materials from the EMRIA Lay Creek, Colorado study site.

### Objectives of study

1. Laboratory characterization to describe the geochemical nature of soil and geologic overburden materials.
2. Greenhouse growth studies and accompanying plant tissue analyses to determine the potential opportunities and/or constraints that these materials offer as plant growth media.
3. Post-harvest laboratory analyses to determine any changes in the chemical nature of the materials as a result of changes in the bio-geochemical weathering environment created by the greenhouse experiment.

### Organic Matter

Determined by wet oxidation with spontaneous heat of reaction. The results are determined colorimetrically and reported as percent organic matter (S.D.M.).

### Plant Available Zinc, Iron, Manganese and Copper, Cadmium, Ni, Pb and Lead

Determined on the static absorption spectrophotometer from an extracting solution of diethylenetriamine pentacetic acid (DTPA). The results are reported in parts per million of Zn, Fe, Mn, Cu, Cd, Ni, and Pb.



## PART I

### PROCEDURES

#### Laboratory Procedures

Following are the laboratory methods used to analyze the soil and geologic material for those properties selected as a basis for determining plant growth suitability.

#### Extractable Phosphorous

Determined on a spectrophotometer from a sodium bicarbonate extract. The values are reported in parts per million P and are an index of available P.

#### Exchangeable Potassium

Determined on the atomic adsorption spectrophotometer from an ammonium acetate extract. The values are reported as parts per million K.

#### Organic Matter

Determined by wet oxidation with spontaneous heat of reaction. The results are determined colorimetrically and reported as percent organic matter (% O.M.).

#### Plant Available Zinc, Iron, Manganese and Copper, Cadmium, Nickel and Lead

Determined on the atomic adsorption spectrophotometer from an extracting solution of diethylenetriamine pentaacetic acid (DTPA). The results are reported in parts per million of Zn, Fe, Mn, Cu, Cd, Ni, and Pb.





### Salinity (Electrical Conductivity)

Determined by a solu-bridge from a saturation extract. The results are reported as electrical conductivity in millimhos per centimeter (mmhos/cm).

### Exchangeable Sodium Percentage (ESP)

Determined by atomic adsorption spectrophotometer and calculated by:

$$ESP = \frac{\text{Exchangeable sodium meq/100 gm}}{CEC} \times 100$$

### Cation Exchange Capacity (CEC)

Determined by:

$$CEC \text{ meq/100g} = \frac{\text{Exchangeable Na meq/l} \times 10}{\text{weight of sample in grams}}$$

### Sodium Adsorption Ratio (SAR)

Prepared from a saturation extract read on the atomic adsorption spectrophotometer and determined by:

$$SAR = \frac{\text{Na}}{\sqrt{\frac{\text{Ca} + \text{Mg}}{2}}}$$

### pH

Determined with a combination electrode pH meter on a saturated soil paste.

### Total Arsenic, Selenium, Boron and Molybdenum

Determined by hot water extractable method on the atomic adsorption spectrophotometer.





## Greenhouse Procedures

### Plant Analysis

Plants were digested with perchloric acid and determinations run on the atomic adsorption spectrophotometer.

### Plant Nitrogen

Determined by the Tecator Block method and read by titration after distillation. Recorded as %N.

Before planting, fertilizer was applied at a rate of 150 ppm nitrogen as reagent grade  $\text{NH}_4\text{NO}_3$ , 80 ppm of phosphorus as a combination of  $\text{KH}_2\text{PO}_4$  and  $\text{CaH}_4(\text{PO}_4)_2 \cdot \text{H}_2\text{O}$  and 80 ppm potassium as  $\text{K}_2\text{O}$ . This was done along with preplant watering.

Before the fertilizer was added, 50-100 g of soil was removed from each pot after which the fertilizer and water was put on. Additional N was applied at 50 ppm rate 21 days after seed emergence.

### Planting

The pots were planted with 75 seeds of western wheatgrass (*Panicum sp.* var. arriha). The seeds were evenly distributed in the pots and covered with the soil that was removed before fertilization.

The pots were covered with plastic to reduce evaporation and were checked daily to assure that the soil remained moist.

After planting, unseasonably hot weather was experienced in the greenhouse being well over  $100^\circ\text{F}$ . The germination almost 100%. After a 20 day period with virtually no germination, we reseeded, placing 50 seeds on top of the soil and covering with vermiculite. This new planting was successful.

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## Greenhouse Procedures

Soil and geologic material received from the Water and Power Resources Service lab had been ground to approximately 2 mm size for greenhouse and additional chemical analyses. One kilogram of soil was used per pot and each pot was replicated. Each sample was placed in a plastic bag in a round container and assigned a greenhouse identification number.

### Fertilizer Treatment

Before planting, fertilizer was applied at a rate of 150 ppm nitrogen as reagent grade  $\text{NH}_4\text{NO}_3$ ; 80 ppm of phosphorus as a combination of  $\text{KH}_2\text{PO}_4$  and  $\text{CaH}_4(\text{PO}_4)_2 \cdot \text{H}_2\text{O}$  and 80 ppm potassium as  $\text{KH}_2\text{PO}_4$ . This was done along with preplant watering.

Before the fertilizer was added, 50-100 g of soil was removed from each pot after which the fertilizer and water was put on. Additional N was applied at 50 ppm rate 21 days after seed emergence.

### Planting

The pots were planted with 75 seeds of western wheatgrass (Agropyron smithii var. arriba). The seeds were evenly distributed in the pots and covered with the soil that was removed before fertilization.

The pots were covered with plastic to reduce evaporation and were checked daily to assure that the soil remained moist.

After planting, unseasonably hot weather was experienced with temperatures in the greenhouse being well over  $100^{\circ}\text{F}$ . This seemed to deter germination almost 100%. After a 20 day period with virtually no germination, we replanted, placing 60 seeds on top of the soil and covering with vermiculite. This new planting was successful.





In this experiment, we did not thin the plants, hoping to have an average of 60 plants per pot. After consulting other researchers involved in similar work as well as from our own experience, we felt that 60 plants would not put undue stress on the pot and our yields would show more significant differences. This would also give us more plant material for plant analysis. An average of 58 plants per pot was calculated for the complete experiment.

### Daily Management

All pots were weighed every other day and brought to field capacity with distilled water. The greenhouse lights were set to allow 15-16 hours of daylight.

Pots were rotated on a regular basis to allow for changes in temperature and lighting within the greenhouse. All pots were randomly arranged on the table.

Seven days after germination, our plants were hit with a fungus with some kill-back on a few pots. We treated this for a two-week period by burning sulfur at night. After the two-week treatment, the plants outgrew the fungus problem.

### Harvest

Generally, we harvest at approximately 48 days after planting, but due to germination and fungus problems combined with a week of cloudy weather, we allowed these plants to go 57 days before harvesting.

The plants were cut at about 2 cm above the soil surface. Plants were then placed in brown paper bags and dried at 60°C for 48-60 hours in a forced air oven. After drying, the plants were weighed and weights recorded.





### Statistical Analysis

Cluster analysis of selected data was performed on all the samples from the Lay Creek Site. The data set used to perform the analysis consisted of pH, organic matter percent, salinity, exchangeable sodium percentage and totals of sand, silt, and clay. This particular set of data was used because the criteria for evaluating these variables are thought to be very reliable. The results of the initial cluster analysis are shown in Table 1.

The purpose of performing a cluster analysis was to statistically develop groups of samples which showed a high degree of association within each group and a low degree of association between groups. The representative groups which were developed served as a pool for selecting samples to perform post-harvest analyses.

### Criteria for Evaluation

The properties considered and criteria used for making suitability interpretations are shown in Table 2.



Table 1. Statistical Grouping of Samples using Cluster Analysis.

| CLUSTER 1       | CLUSTER 5 | CLUSTER 7 |
|-----------------|-----------|-----------|
| DH-1 #1         | DH-2 c    | DH-3 e    |
| DH-1 #2         | DH-2 d    | DH-3 h    |
| DH-1 b          | DH-2 h    | DH-3 k    |
| DH-2 e          | DH-2 j    | DH-3 n    |
| DH-2 f          | DH-2 k    | DH-4 l    |
| DH-2 i          | DH-3 l    |           |
| DH-3 #1         |           |           |
| DH-4 #1         |           |           |
| DH-2 #1 Control |           |           |
| CLUSTER 2       | CLUSTER 6 | CLUSTER 8 |
| DH-1 #3         | DH-3 c    | DH-3 i    |
| DH-1 #4         | DH-3 d    | DH-3 m    |
| DH-1 a          | DH-3 f    | DH-4 k    |
| DH-2 #2         | DH-3 j    |           |
| DH-2 a          | DH-3 o    |           |
| DH-2 b          | DH-4 b    |           |
| DH-2 g          | DH-4 c    |           |
| DH-3 #2         | DH-4 d    |           |
| DH-3 #3         | DH-4 e    |           |
| DH-3 a          | DH-4 f    |           |
| DH-3 b          | DH-4 g    |           |
| DH-4 #2         | DH-4 h    |           |
| DH-4 #5         | DH-4 i    |           |
| DH-4 a          | DH-4 j    |           |
|                 | DH-4 m    |           |
|                 | DH-3 g    |           |
| CLUSTER 3       |           |           |
| DH-2 #3         |           |           |
| DH-4 #3         |           |           |
| DH-4 #4         |           |           |
| CLUSTER 4       |           |           |
| DH-2 #4         |           |           |





Table 2. Criteria for evaluating laboratory characterization data for determining plant growth suitability.<sup>1</sup>

| <u>Texture</u>              |  |               |
|-----------------------------|--|---------------|
| <u>Texture Class</u>        |  | <u>Rating</u> |
| very fine sandy loam (vfs1) |  | good          |
| fine sandy loam (fs1)       |  | good          |
| sandy loam (s1)             |  | good          |
| loam (1)                    |  | good          |
| silt loam (sil)             |  | good          |
| loamy fine sand (lfs)       |  | fair          |
| loamy sand (ls)             |  | fair          |
| clay loam (cl)              |  | fair          |
| sandy clay loam (scl)       |  | fair          |
| silty clay loam (sicl)      |  | fair          |
| sand (s)                    |  | poor          |
| clay (c)                    |  | poor          |
| sandy clay (sc)             |  | poor          |
| silty clay (sic)            |  | poor          |
| <u>pH</u>                   |  |               |
| <u>pH</u>                   |  | <u>Rating</u> |
| 6.0-8.4                     |  | good          |
| 5.0-6.0; 8.4-8.9            |  | fair          |
| <5.0; >8.9                  |  | poor          |

<sup>1</sup>Guidelines developed by the Western Regional Soil Survey Work Planning Committee on "Guidelines for Evaluating Soil and Overburden Characteristics in Strip-Mine Reclamation."





Table 2. (continued)

Available Phosphorus<sup>2</sup>

| <u>Soil Test - ppm P</u> | <u>Soil Phosphorus Fertility Status</u> |
|--------------------------|-----------------------------------------|
| 0-7                      | deficient                               |
| >7                       | adequate                                |

Available Potassium<sup>2</sup>

| <u>Soil Test - ppm K</u> | <u>Soil Potassium Fertility Status</u> |
|--------------------------|----------------------------------------|
| 0-60                     | deficient                              |
| >60                      | adequate                               |

Available Zinc<sup>2</sup>

| <u>Soil Test - ppm Zn</u> | <u>Availability Status</u> |
|---------------------------|----------------------------|
| 0-0.5                     | potentially deficient      |
| >0.5                      | adequate                   |

Available Iron<sup>2</sup>

| <u>Soil Test - ppm Fe</u> | <u>Availability Status</u> |
|---------------------------|----------------------------|
| 0-2.0                     | potentially deficient      |
| >2.0                      | adequate                   |

Available Copper and Manganese<sup>2</sup>

| <u>Soil Test - ppm Cu or Mn</u> | <u>Availability Status</u> |
|---------------------------------|----------------------------|
| 0-0.5                           | potentially deficient      |
| >0.5                            | adequate                   |

<sup>2</sup>Colorado State University Soil Testing Laboratory soil interpretation guidelines.





Table 2. (Continued)

| <u>Salinity</u> <sup>3</sup> |                                |
|------------------------------|--------------------------------|
| <u>Soil Test - mmhos/cm</u>  | <u>Rating</u>                  |
| 0-4                          | <i>low</i> acceptable          |
| 4-8                          | <i>med</i> marginal            |
| <i>7-12</i><br>>8-12         | <i>High</i> poor to unsuitable |
|                              | <i>unsuitable</i>              |

| <u>Sodium</u> <sup>4</sup>         |                |
|------------------------------------|----------------|
| <u>Exchangeable Sodium Percent</u> | <u>Rating</u>  |
| 0-10                               | acceptable     |
| 10-15                              | marginal       |
| >15                                | non-acceptable |

#### Evaluating Toxic Elements

The toxic elements considered and evaluated in this study are those thought to be of most importance from the standpoint of toxicity to plants, fish, animals and man.

Toxicity of these elements to plants, animals and man have been reported for some elements, but in most cases, well accepted critical levels have not been established.

Our approach in this study has been to evaluate soil, geologic and plant tissue analyses data to determine if levels are approaching what the current state of the art is relative to potential toxicity problems and then identifying and discussing a particular problem on a sample by sample basis. Our sources of literature for making these evaluations are listed below.

<sup>3</sup>Based on Water and Power Resource Service Land Suitability Classification Salinity Evaluation.

<sup>4</sup>From "Procedures Recommended for Overburden and Hydrologic Study of Surface Mines" (Heil, Deutsch, et al, 1979).





The current thought by our group is that there is insufficient criteria available for establishing interpretive guidelines for evaluating potential toxicity problems as was done for other factors identified in table 2. The "state of the art knowledge" dictates that we evaluate toxicity problems on a sample by sample-element by element basis using the most current and what appears to be the most applicable information available at this particular time. Sources of information utilized for making our evaluations are listed below.

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## PART II

### PLANT GROWTH SUITABILITY EVALUATION BASED ON LABORATORY CHARACTERIZATION

This portion of the evaluation and characterization study involved two steps. An initial evaluation was performed to identify the chemical and/or physical problems associated with the materials that influence plant growth. This resulted in the development of "Problem Identification Categories." Secondly, the "Problem Identification Categories" were further grouped into what are described as "Problem Area Groups." The purpose of this latter grouping was to aggregate "Problem Identification Categories" such as fertility, salinity, pH, texture, etc., into more meaningful and manageable groups for evaluating the magnitude of potential long term management and environmental concerns. Following is described the evaluation process used for interpreting plant growth suitability on the basis of laboratory characterization data.

#### Development of Problem Identification Categories

Basic to determining plant growth suitability is the identification of the specific kinds of problems that affect the use of a material for this purpose. The properties considered and criteria used for interpretation in this part of the study are shown in Table 2. The chemical and physical data used for this evaluation are shown in Appendix Table 1. This step in the evaluation process resulted in the identification of 26 "Problem Identification Categories" which are described in Table 3.





Table 3. Description of "Problem Identification Categories."

| Problem Identification Categories | Site Sample Number                              | Description                                                           |
|-----------------------------------|-------------------------------------------------|-----------------------------------------------------------------------|
| 1                                 | DH-1 #1, DH-1 #4, DH-2a, DH-2b, DH-2c, DH-2e    | P-deficient                                                           |
| 2                                 | DH-1 #3, DH-2 #1, DH-2 #2, DH-2g, DH-2i         | P-deficient, pH fair                                                  |
| 3                                 | DH-2j                                           | P-deficient, pH poor, Cu & Mn potentially deficient                   |
| 4                                 | DH-2h                                           | P-deficient, Cu potentially deficient, pH poor                        |
| 5                                 | DH-1a                                           | texture fair                                                          |
| 6                                 | DH-3 #1                                         | P-deficient, texture fair                                             |
| 7                                 | DH-1b, DH-2f                                    | P-deficient, texture poor                                             |
| 8                                 | DH-3 #2, DH-4 #1                                | P-deficient, pH fair, texture fair                                    |
| 9                                 | DH-1 #2                                         | P-deficient, Cu potentially deficient, texture fair                   |
| 10                                | DH-3 #3                                         | P-deficient, Cu potentially deficient, pH fair, texture fair          |
| 11                                | DH-2d                                           | P-K deficient, pH fair, Cu potentially deficient, texture fair        |
| 12                                | DH-3l                                           | P-K deficient, pH poor, Cu potentially deficient, texture fair        |
| 13                                | DH-2k                                           | P-K deficient, Cu potentially deficient, sodium marginal              |
| 14                                | DH-4 #2                                         | P-deficient, pH fair, sodium marginal                                 |
| 15                                | DH-4 #5                                         | P-deficient, pH fair, sodium unacceptable                             |
| 16                                | DH-3b, DH-3e, DH-3h, DH-3i, DH-3k, DH-3o, DH-4e | P-deficient, pH poor, sodium unacceptable                             |
| 17                                | DH-3n                                           | P-K deficient, pH poor, Cu potentially deficient, sodium unacceptable |





Table 3. (continued)

| Problem Identification Categories | Site Sample Number                                            | Description                                                         |
|-----------------------------------|---------------------------------------------------------------|---------------------------------------------------------------------|
| 18                                | DH-4l                                                         | K-deficient, pH poor, Cu potentially deficient, sodium unacceptable |
| 19                                | DH-4 #3                                                       | Salinity marginal, sodium marginal                                  |
| 20                                | DH-4h, DH-4j, DH-4k                                           | pH fair, sodium unacceptable, texture fair                          |
| 21                                | DH-3a                                                         | P-deficient, pH poor, sodium marginal, texture poor                 |
| 22                                | DH-4 #4                                                       | P-deficient, salinity marginal, sodium marginal                     |
| 23                                | DH-2 #3                                                       | pH fair, salinity marginal, sodium unacceptable                     |
| 24                                | DH-2 #4                                                       | Fe and Cu potentially deficient, salinity poor, sodium marginal     |
| 25                                | DH-3c, DH-4d, DH-4f, DH-4i, DH-4m                             | P-deficient, pH poor, sodium unacceptable, texture poor             |
| 26                                | DH-3d, DH-3f, DH-3g, DH-3j, DH-3m, DH-4b, DH-4c, DH-4g, DH-4a | P-deficient, pH poor, sodium unacceptable, texture fair             |





A study of these categories indicates that the following specific kinds of limitations exist in terms of the suitability of the materials as plant growth media.

1. Phosphorus and/or potassium deficiencies are common to nearly all samples.
2. Micronutrient deficiencies are common with deficiencies in copper being the most common. It is important to point out that the criteria used for evaluating micronutrient deficiencies are based on deficiencies associated with agronomic crops sensitive to these elements. Thus, the micronutrient deficiencies must be considered somewhat arbitrary. Overall, we suspect that micronutrients would not be a major fertility problem.
3. Texture has been identified as being a potential concern with a large number of samples. High runoff potential and erosion due to the slow infiltration rates of fine textured materials would be the major problem. The high runoff potential is a concern both as it affects environmental quality as well as plant growth.
4. Sodium problems are common to many materials.
5. High pH. -- Some question could be raised concerning the utilization of pH as a single criteria for evaluating the suitability of materials. According to the criteria shown in Table 2, a number of materials would be rated poor based on high pH. Yet the yield data shown in Table 6 of this report would suggest that in several cases (compare yield and laboratory data for samples DH-2j and DH-2g), pH should not be used as an indicator of suitability. We developed the "Problem Identification Categories " and "Problem





Area Groups" by strictly following the criteria shown in Table 2.

Modification of our interpretations based on pH may be appropriate.

OK  
good thinking

In summary, deficiencies in phosphorus, potassium and possibly copper; high levels of sodium; high pH; and texture appear to be the kinds of specific problems associated with the materials studied in terms of plant growth suitability.





#### Development and Description of "Problem Area Groups"

The development of "Problem Identification Categories" was the first step in evaluation of materials for plant growth media. Recognizing that some of these categories could be grouped on the basis of problem areas, i.e., fertility, texture, etc., we further grouped the categories into "Problem Area Groups." This grouping better identifies the magnitude of the kinds and combinations of problems and are more meaningful from a management decision point of view.

Descriptions of the "Problem Area Groups" and the basis used for determining relative suitability rating are shown in Table 4.

A summary of relative suitability ratings by "Problem Area Groups" are shown in Table 5.

5. Fertility,  
texture poor

This includes category 5 and is characterized by P-deficiency and clay loam texture. Problems due to erosion may be a problem.

6. Fertility,  
texture fair,  
oil fair

This includes category 7 and is characterized by P-deficiency and clay texture. Clay materials have a high water erosion potential and if erosion occurs may affect environmental quality. These materials may be questionable due to potential erosion problems.

7. Fertility,  
oil poor,  
texture fair

This includes categories 8, 9, 10 and 11 and is characterized by P alone or either with K and Ca deficiency. pH is fair and texture is clay loam or heavy sand. This increased susceptibility to erosion from either water (oil) or wind (K). These materials are classified as questionable.

This includes category 12 where there is P and K deficiency along with Ca potential deficiency. The pH is high, over 8.5 and the texture is a heavy sand susceptible to wind erosion and also may limit available water for plant growth. These materials are classified as questionable because of pH and texture.





Table 4. Descriptions of "Problem Area Groups."

| Problem Area Groups                       | Description and Basis for Suitability Rating                                                                                                                                                                                                                                                                        |
|-------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. Fertility<br>pH fair                   | This group includes Problem Identification Categories 1 and 2. P-deficiency alone affects this group of materials as a plant growth media. These materials are suitable as plant growth media if fertilizers are added to eliminate the deficiency. These materials are classed as suitable.                        |
| 2. Fertility<br>pH poor                   | This includes categories 3 and 4 and is characterized by P deficiency. The pH value is over 8.9. These materials are classed as questionable because of high pH. <i>OK</i>                                                                                                                                          |
| 3. Texture, fair                          | This includes category 5 and silty clay loam texture increases the material's potential erosiveness. This material is classified as suitable.                                                                                                                                                                       |
| 4. Fertility,<br>texture fair             | This includes category 6 and is characterized by P-deficiency and clay loam texture. Problems due to erosion may be a problem.                                                                                                                                                                                      |
| 5. Fertility,<br>texture poor             | This includes category 7 and is characterized by P-deficiency and clay textures. Clay materials have a high water erosion potential and if erosion occurs may affect environmental quality. These materials may be questionable due to potential erosion problems.                                                  |
| 6. Fertility,<br>texture fair,<br>pH fair | This includes categories 8, 9, 10 and 11 and is characterized by P alone or either with K and Cu deficiency. pH is fair and texture is clay loam or loamy sands. This increased susceptibility to erosion from either water (CL) or wind (LS). These materials are classified as questionable.                      |
| 7. Fertility,<br>pH poor,<br>texture fair | This includes category 12 where there is P and K deficiency along with Cu potential deficiency. The pH is high, over 8.9 and the texture is a loamy sand susceptible to wind erosion and also may limit available water for plant growth. These materials are classified as questionable because of pH and texture. |





8. Fertility,  
Sodium marginal  
This includes category 13 where there is a P-K deficiency along with potentially deficient Cu and a marginal sodium level. Marginal sodium level increases water erosion potential by reducing the amount of plant growth and decreasing infiltration rates, thus causing more runoff. Materials in this group are classified as unsuitable.
9. Fertility,  
pH fair,  
Sodium marginal  
This includes category 14. P deficiency, marginal sodium and pH of 8.4-8.9 characterize this group. This material may be considered unsuitable because of potential effect of sodium.
10. Fertility,  
pH fair-poor,  
Sodium marginal  
This includes Problem Identification Categories 15, 16, 17, and 18. These include P or K alone or together with Cu potential deficiency, a pH of generally more than 8.9 and high sodium. Due to detrimental affects of sodium and high pH on plant growth and potential erosion problems caused by same, this group is classified as unsuitable.
11. Salinity marginal,  
sodium marginal  
This includes Problem Identification Category 19 and is characterized by a conductivity of 4-8 mmhos/cm. Marginal salinity levels may affect plant growth unless salt tolerant species are selected. The materials are classed as questionable due to salinity and sodium.
12. pH fair, sodium  
unacceptable,  
texture fair  
This includes category 20 with pH of 8.4-8.9, high sodium levels and clay loam or silty clay loam textures. Due to effect of high sodium, these materials are classified as unsuitable.
13. Fertility,  
pH poor, Sodium  
marginal,  
texture poor  
This includes category 21 and is characterized by P-deficiency, pH of over 8.9, a moderate sodium and fine texture. The high pH with an erosion potential caused by the moderate sodium in combination with the silty clay make this material unsuitable for plant growth.
14. Fertility,  
salinity marginal,  
sodium marginal  
This includes Identification Category 22 and is characterized by P deficiency, a moderate salt and sodium problem. This material is classified questionable for plant growth.
15. pH fair,  
salinity marginal,  
sodium unacceptable  
This includes Problem Identification Category 23 and has a pH of 8.4-8.9, a moderate salinity, and very high sodium level making it unsuitable to all but very salt tolerant plant growth. This material is classified as unsuitable.





16. Fertility, salinity This includes Problem Identification Category 24  
poor, sodium and is characterized by potential Cu and Fe  
marginal deficiency along with salinity at a level over  
8 mmhos/cm and moderate sodium levels. Due to  
erosion and salt problems these materials are  
classified as unsuitable.
17. Fertility, This includes categories 25 and 26 and are seen  
pH poor, to have P-deficiency along with very high pH  
sodium over 8.9, high sodium (ESP 15 or over) and  
unacceptable, textures of silty clays, clay, and clay loams.  
texture fair to The combination of high sodium and poor textures  
poor tends to suggest permeability and erosion  
problems and makes these materials unsuitable  
for plant growth media.





Table 5. Summary of Suitability Ratings developed on the Basis of Laboratory Characterization Data.

| <u>Problem Area Group Number</u> | <u>Relative Rating</u> |
|----------------------------------|------------------------|
| 1                                | Suitable               |
| 2                                | Questionable           |
| 3                                | Suitable               |
| 4                                | Suitable               |
| 5                                | Questionable           |
| 6                                | Questionable           |
| 7                                | Questionable           |
| 8                                | Unsuitable             |
| 9                                | Unsuitable             |
| 10                               | Unsuitable             |
| 11                               | Questionable           |
| 12                               | Unsuitable             |
| 13                               | Unsuitable             |
| 14                               | Questionable           |
| 15                               | Unsuitable             |
| 16                               | Unsuitable             |
| 17                               | Unsuitable             |



### PART III

#### POST HARVEST EVALUATION

In addition to the physical and chemical data shown in Appendix Table 1, analyses were carried out to identify and evaluate changes in chemical characteristics as a result of the weathering environment created in the greenhouse experiment. Post-harvest analyses of selected samples consisted of plant available P and K; DTPA extractable Zn, Fe, Mn, Cu, Cd, Ni and Pb; pH; electrical conductivity; cation exchange capacity; exchangeable sodium percentage; sodium adsorption ratios; and hot water extractable B, Mo, As and Se. Representative samples, based on pre-harvest chemical analyses were selected from each of seven computer generated cluster analyses groups. Post-harvest soil analyses results are shown in Table 2 of the Appendix.

A summary of the post-harvest chemical analyses shown in Appendix Table 2 show the following important relationships:

1. The pH values of all selected samples show a marked decrease from pre-plant to post-harvest. The changes range from 0.6 to 1.9 for the soil materials and 1.7 to 2.0 for the geologic overburden materials. We feel these changes are a result of high levels of  $\text{CO}_2$  production by plant roots and a reaction product of carbonic acid forming when  $\text{CO}_2$  and water are combined. In a field situation, this pH change would be restricted to the plant rooting zone and should be highly correlated to the amount





of root biomass produced.

Researching the impacts or significance of these changes in pH is beyond the scope of this study. These results do, however, indicate that long term studies are needed to monitor changes in the chemical properties, particularly of the geologic materials, when the bio-geochemical environment is altered.

2. The pre-plant vs. post-harvest electrical conductivities increased in all samples tested. The magnitude of increase for all but the surface soil samples (DH-1 #1; DH-4 #1; DH-2 #1; DH-1 #3) was great enough to shift the ratings to a lesser degree of suitability, i.e., acceptable materials became marginal; marginal materials became unsuitable, etc. It must be noted that the greenhouse pots were not freely drained, thus salts could accumulate. This may not happen in a well-drained field situation. Thus, the rating of materials was not changed due to this factor.
3. In most cases the exchangeable sodium percentages (ESP) decreased. These decreases ranged from 0.2 to 12.0 percent. The magnitude of decrease in each case was not large enough to shift the suitability ratings. It appears from pre-plant vs. post-harvest ESP data that materials with initially high values will remain at a critical level (marginal to non-acceptable) from a plant growth or environmental quality point of view. Likewise, materials with initially low ESP values will remain at a level that will not be detrimental to plant growth. However, we cannot say that equilibrium conditions were reached in the greenhouse study. Thus, it would not be appropriate to use the post harvest data to alter our initial interpretation.





4. Post-harvest analyses of the selected materials showed a reduction from adequate to potentially deficient in plant available zinc in the soil materials. (DH-1 #1; DH-4 #1; DH-2 #1; DH-1 #3; DH-4 #5; DH-4 #4). Zinc levels remained at an adequate level in the geologic materials from the pre-plant through post-harvest period.
5. Extractable data on post-harvest levels of Cd, Ni, Pb, B, Mo, As, and Se appear to be relatively low and do not indicate any potential problems. Levels of As and Se for all samples were below the detection limit of 0.5 ppm. It is important to note that even though extractable chemical analyses data closely approximate the actual soil solution condition, very little data is available that correlates plant uptake with extractable levels of elements, particularly with regard to native species.





Table 6 Average Yield Values for Samples within each Problem Area Group

| Problem Area Group | Sample Number | Average Yield | Problem Area Group | Sample Number | Average Yield |
|--------------------|---------------|---------------|--------------------|---------------|---------------|
|--------------------|---------------|---------------|--------------------|---------------|---------------|

#### PART IV

#### GREENHOUSE GROWTH STUDY AND PLANT TISSUE ANALYSES

Greenhouse growth studies along with plant tissue analyses were carried out to aid in evaluation of materials as plant growth media and to verify any performance and/or plant growth characteristics predicted from laboratory characterization data of the overburden materials studied.

The results of this study are shown in Table 6 by sample within each "Problem Area Group." Yields reported reflect the mean value for all replications of the material.

The results of the greenhouse study appear to indicate the following:

1. Sodium(ESP) and/or salinity (EC) showed a depressing effect on yields as their concentrations increased in materials.
2. Materials affected only with fertility, pH and texture as potential problems showed consistently the highest yields for the experiment. (Problem Area Groups 1, 3 and 4).
3. Materials in "Problem Area Groups" 8, 13 and 16 show yields approaching those of the best materials identified in 2 above. These groups are typified by being classed as marginal in regards to sodium but are only a percent or two above the acceptable limit set at 10%.
4. "Problem Area Group" 7 shows an average yield of 2.47 gram/pot. Materials within the group have a texture of loamy sand and although they performed well in the greenhouse, they were rated as questionable for plant growth because of droughtiness.





Table 6. Average Yield Values for Samples within each Problem Area Group.

| Problem Area Group | Sample Number | Average Yield | Problem Area Group | Sample Number | Average Yield |
|--------------------|---------------|---------------|--------------------|---------------|---------------|
| 1                  | DH-1 #1       | 2.34          | 10                 | DH-4 #5       | 2.47          |
|                    | DH-1 #4       | 2.56          |                    | DH-3b         | 1.91          |
|                    | DH-2a         | 2.37          |                    | DH-3e         | 2.15          |
|                    | DH-2b         | 2.66          |                    | DH-3h         | 2.25          |
|                    | DH-2c         | 1.54          |                    | DH-3i         | 1.24          |
|                    | DH-2e         | 2.50          |                    | DH-3k         | 1.16          |
|                    | DH-1 #3       | 2.49          |                    | DH-3o         | 1.96          |
|                    | DH-2 #1       | 2.02          |                    | DH-4e         | 1.87          |
|                    | DH-2 #2       | 2.31          |                    | DH-3n         | 2.09          |
|                    | DH-2g         | 1.91          |                    | DH-4l         | 2.39          |
|                    | DH-2i         | 2.05          | 11                 | DH-4 #3       | 1.72          |
| 2                  | DH-2j         | 2.16          |                    | DH-4h         | 1.38          |
|                    | DH-2h         | 1.79          | 12                 | DH-4j         | 1.34          |
| 3                  | DH-1a         | 2.00          |                    | DH-4k         | 1.65          |
| 4                  | DH-3 #1       | 2.14          | 13                 | DH-3a         | 2.09          |
| 5                  | DH-1b         | 1.75          | 14                 | DH-4 #4       | 1.44          |
|                    | DH-2f         | 1.96          | 15                 | DH-2 #3       | 1.81          |
| 6                  | DH-3 #2       | 1.34          | 16                 | DH-2 #4       | 2.10          |
|                    | DH-4 #1       | 1.60          | 17                 | DH-3c         | 1.88          |
|                    | DH-1 #2       | 1.54          |                    | DH-4d         | 1.70          |
|                    | DH-3 #3       | 1.46          |                    | DH-4f         | 1.81          |
|                    | DH-2d         | 1.83          |                    | DH-4i         | 1.46          |
| 7                  | DH-3l         | 2.47          |                    | DH-4m         | 1.77          |
| 8                  | DH-2k         | 2.04          |                    | DH-3d         | 1.77          |
| 9                  | DH-4 #2       | 1.85          |                    | DH-3f         | 2.15          |
|                    |               |               |                    | DH-3g         | 1.22          |
|                    |               |               |                    | DH-3j         | 1.71          |
|                    |               |               |                    | DH-3m         | 1.49          |
|                    |               |               |                    | DH-4b         | 1.78          |
|                    |               |               |                    | DH-4c         | 1.59          |
|                    |               |               |                    | DH-4g         | 1.78          |
|                    |               |               |                    | DH-4a         | 1.20          |





Plant tissue analyses data from selected materials are shown in Table 7. These selected samples correspond to the samples used for post-harvest laboratory analyses as identified in Part III of this report.

A review of the plant tissue analyses data indicates the following:

1. Total zinc concentrations are higher in plants from the geologic overburden materials than those from soils. This correlates well with pre-plant vs. post-harvest analyses which show a decrease in available zinc for soil materials and are unchanged or increase in geologic overburden material. Chapman (1966) reported zinc deficiency symptoms in oats and corn at levels of less than 20 ppm and 9-15 ppm respectively. While samples DH-1-1, DH-1-3, DH-4-1, and DH-4-5 are within this deficiency range, the wheat grass grown showed no deficiency symptoms. It should be kept in mind that species vary greatly in their need and tolerance of micro-nutrients. Heil and Deutsch (1980)<sup>1</sup> have shown zinc response on western wheatgrass (*Agropyron smithii*) grown on soil and geologic overburden materials from the Bureau of Land Management's McCallum, Colorado site. Samples from Lay Creek appear to be very similar in physical and chemical characteristics to McCallum samples and therefore have the potential to be zinc deficient.
2. Total concentrations of the elements studied in plant tissue appear to be well within published tolerance ranges for most

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<sup>1</sup>Data to be presented in final report of the EMRIA-McCALLUM, Colorado SITE results.





agronomic crops (Chapman 1966; Gough and Shacklette 1976) and therefore acceptable from a plant growth and environmental quality point of view.

It appears that good correlation exists between pre-plant, post-harvest and plant tissue analyses on all samples tested. It appears that any changes which occurred as a result of weathering during the greenhouse experiment were not of a magnitude which would affect plant growth.

Table 7. Analysis of plants grown on selected materials.

| Cluster Sample No. | P    | K    | Ca   | Mg   | Na   | Zn | Fe  | No  |
|--------------------|------|------|------|------|------|----|-----|-----|
| 1                  | 0.15 | 3.22 | 0.51 | 0.32 | 0.01 | 5  | 56  | 68  |
| 2                  | 0.38 | 3.45 | 0.51 | 0.34 | 0.01 | 8  | 126 | 51  |
| 3a-4 #1 A          | 0.26 | 3.36 | 0.56 | 0.34 | 0.05 | 11 | 157 | 108 |
| B                  | 0.19 | 3.72 | 0.33 | 0.35 | 0.06 | 10 | 103 | 81  |
| 3a-2 #1 A          | 0.24 | 3.36 | 0.55 | 0.26 | 0.01 | 14 | 45  | 70  |
| Control B          | 0.34 | 3.44 | 0.43 | 0.30 | 0.01 | 6  | 56  | 74  |
| 4a-1 #1 A          | 0.26 | 2.92 | 0.35 | 0.44 | 0.03 | 27 | 122 | 163 |
| B                  | 0.24 | 2.90 | 0.31 | 0.43 | 0.03 | 75 | 75  | 134 |
| 5a-4 #1 A          | 0.17 | 3.15 | 0.36 | 0.27 | 0.14 | 8  | 76  | 112 |
| B                  | 0.14 | 3.22 | 0.37 | 0.27 | 0.14 | 9  | 43  | 100 |
| 6a-4 #1 A          | 0.24 | 3.35 | 0.43 | 0.35 | 0.20 | 11 | 72  | 102 |
| B                  | 0.20 | 3.22 | 0.39 | 0.32 | 0.12 | 7  | 128 | 140 |
| 7a-3a A            | 0.24 | 3.75 | 0.40 | 0.19 | 0.05 | 7  | 43  | 167 |
| B                  | 0.18 | 3.95 | 0.33 | 0.19 | 0.16 | 3  | 27  | 163 |
| 8a-21 A            | 0.15 | 2.90 | 0.34 | 0.21 | 0.07 | 45 | 103 | 111 |
| B                  | 0.16 | 2.98 | 0.57 | 0.20 | 0.07 | 44 | 124 | 100 |
| 9a-3a A            | 0.11 | 3.68 | 0.35 | 0.13 | 0.19 | 18 | 208 | 177 |
| B                  | 0.19 | 3.72 | 0.31 | 0.14 | 0.15 | 15 | 105 | 108 |
| 10a-41 A           | 0.15 | 3.96 | 0.24 | 0.15 | 0.17 | 19 | 78  | 126 |
| B                  | 0.24 | 3.10 | 0.32 | 0.15 | 0.15 | 3  | 49  | 49  |
| 11a-3a A           | 0.18 | 3.25 | 0.29 | 0.15 | 0.14 | 14 | 40  | 154 |
| B                  | 0.15 | 3.36 | 0.27 | 0.16 | 0.15 | 19 | 101 | 140 |
| 12a-41 A           | 0.16 | 3.34 | 0.23 | 0.19 | 0.10 | 4  | 104 | 176 |
| B                  | 0.17 | 3.30 | 0.24 | 0.17 | 0.16 | 6  | 115 | 178 |

Note: As, Fe and Pb are below 10 ppm / not shown. Moist.





Table 7. Analysis of plants grown on selected materials.

| Cluster | Sample No. | P    | K    | Ca   | Mg   | Na    | B  | Zn | Fe  | Mn  | Cu | Ni  | Mo   | Cd | % N  |
|---------|------------|------|------|------|------|-------|----|----|-----|-----|----|-----|------|----|------|
| 1       | DH-1 #1 A  | 0.26 | 3.22 | 0.61 | 0.22 | <0.01 | 5  | 12 | 56  | 68  | 6  | <2  | <2   | <2 | 3.84 |
|         | B          | 0.30 | 3.46 | 0.61 | 0.24 | <0.01 | 5  | 13 | 126 | 51  | 7  | <2  | <2   | <2 | 3.84 |
|         | DH-4 #1 A  | 0.26 | 3.36 | 0.66 | 0.33 | 0.05  | 11 | 11 | 157 | 109 | 10 | <2  | <2   | <2 | 3.89 |
|         | B          | 0.29 | 3.72 | 0.73 | 0.38 | 0.06  | 10 | 9  | 103 | 81  | 10 | <2  | <2   | <2 | 3.79 |
|         | DH-2 #1 A  | 0.24 | 3.36 | 0.56 | 0.20 | <0.01 | 14 | 19 | 48  | 78  | 6  | <2  | <2   | <2 | 3.64 |
|         | Control B  | 0.34 | 3.44 | 0.48 | 0.20 | <0.01 | 3  | 22 | 86  | 74  | 7  | <2  | <2   | <2 | 3.64 |
| 2       | DH-1 #3 A  | 0.26 | 2.96 | 0.35 | 0.44 | 0.03  | 27 | 7  | 102 | 166 | 10 | 2.5 | 14.1 | <2 | 3.39 |
|         | B          | 0.24 | 2.90 | 0.30 | 0.43 | 0.03  | 26 | 7  | 75  | 164 | 11 | 2.6 | 13.1 | <2 | 3.03 |
|         | DH-4 #5 A  | 0.17 | 3.28 | 0.39 | 0.27 | 0.14  | 9  | 14 | 76  | 112 | 10 | 2.0 | <2   | <2 | 3.56 |
|         | B          | 0.14 | 3.22 | 0.37 | 0.27 | 0.14  | 9  | 14 | 63  | 102 | 9  | 2.5 | <2   | <2 | 3.28 |
| 3       | DH-4 #4 A  | 0.24 | 3.35 | 0.43 | 0.33 | 0.20  | 11 | 16 | 72  | 180 | 12 | <4  | <4   | <4 | 3.92 |
|         | B          | 0.20 | 3.42 | 0.34 | 0.28 | 0.16  | 7  | 14 | 128 | 160 | 11 | <2  | <2   | <2 | 3.89 |
| 5       | DH-2h A    | 0.26 | 3.75 | 0.40 | 0.19 | 0.06  | 7  | 55 | 48  | 163 | 9  | <4  | <4   | <4 | 4.56 |
|         | B          | 0.18 | 3.55 | 0.33 | 0.19 | 0.19  | 3  | 31 | 27  | 163 | 7  | <4  | <4   | <4 | 3.05 |
|         | DH-31 A    | 0.15 | 2.90 | 0.54 | 0.21 | 0.07  | 46 | 37 | 103 | 111 | 7  | <2  | 3.6  | <2 | 3.42 |
|         | B          | 0.14 | 2.98 | 0.57 | 0.20 | 0.07  | 44 | 32 | 136 | 103 | 5  | <2  | 2.2  | <2 | 3.39 |
| 6       | DH-3g A    | 0.21 | 3.68 | 0.33 | 0.19 | 0.19  | 15 | 30 | 231 | 177 | 9  | <4  | <4   | <4 | 3.86 |
|         | B          | 0.19 | 3.72 | 0.31 | 0.18 | 0.26  | 15 | 33 | 105 | 159 | 9  | <2  | 3.5  | <2 | 3.86 |
|         | DH-4i A    | 0.19 | 3.36 | 0.24 | 0.15 | 0.17  | 10 | 41 | 74  | 108 | 11 | <2  | <2   | <2 | 4.37 |
|         | B          | 0.24 | 3.10 | 0.22 | 0.16 | 0.18  | 3  | 49 | 89  | 93  | 12 | <2  | 2.7  | <2 | 4.20 |
| 7       | DH-3h A    | 0.18 | 3.26 | 0.29 | 0.16 | 0.14  | 14 | 35 | 60  | 151 | 6  | <2  | 3.6  | <2 | 3.50 |
|         | B          | 0.15 | 3.28 | 0.27 | 0.16 | 0.15  | 10 | 29 | 101 | 190 | 6  | <2  | 3.6  | <2 | 3.16 |
| 8       | DH-4k A    | 0.16 | 3.34 | 0.23 | 0.19 | 0.18  | 4  | 29 | 164 | 216 | 7  | <2  | 3.9  | <2 | 3.25 |
|         | B          | 0.17 | 3.30 | 0.24 | 0.17 | 0.16  | 6  | 27 | 112 | 179 | 8  | <2  | 3.1  | <2 | 2.49 |

Note: As, Se and Pb fell below 10 ppm (the detection limit).





## APPENDIX



Table 1. Laboratory characterization data (pre-plant analyses).

| Site<br>Sample No. | Depth<br>Ft. | pH   | DTPA Ext. ppm |     |      |      | NaHCO <sub>3</sub><br>P<br>ppm | NH <sub>4</sub> OAC<br>K<br>ppm | %<br>O.M. | mmhos/cm           |       | meq/100g |      | %<br>S | %<br>Si | %<br>C |
|--------------------|--------------|------|---------------|-----|------|------|--------------------------------|---------------------------------|-----------|--------------------|-------|----------|------|--------|---------|--------|
|                    |              |      | Fe            | Zn  | Mn   | Cu   |                                |                                 |           | ECx10 <sup>3</sup> | SAR   | C.E.C.   | ESP  |        |         |        |
| DH-1 #1            | 0-.5         | 8.0  | 12.0          | 2.8 | 5.1  | .80  | .30                            | 144.0                           | 2.20      | .27                | .20   | 15.06    | .9   | 53.4   | 28.8    | 17.8   |
| DH-1 #2            | .5-3.5       | 8.2  | 4.0           | 2.3 | 3.4  | .40  | .30                            | 72.0                            | 1.25      | .41                | .60   | 21.25    | 2.2  | 27.8   | 43.6    | 28.6   |
| DH-1 #3            | 3.5-7        | 8.9  | 3.8           | 2.2 | 1.6  | .58  | .30                            | 98.4                            | .45       | .75                | 5.70  | 18.44    | 7.7  | 32.6   | 40.2    | 27.2   |
| DH-1 #4            | 7-10         | 8.4  | 4.8           | 2.2 | 1.2  | .76  | .30                            | 134.4                           | .55       | 2.99               | 5.10  | 18.75    | 6.7  | 33.4   | 41.8    | 24.8   |
| DH-1 a             | 42-50.6      | 8.2* | 12.6          | 2.9 | 2.2  | 3.04 | 30.38                          | 84.0                            | .85       | 1.02               | .50   | 9.25     | 2.9  | 14.4   | 57.8    | 27.8   |
| DH-1 b             | 52.5-58      | 7.8* | 29.4          | 5.5 | 16.4 | 3.72 | 0                              | 122.4                           | 1.70      | 2.08               | .40   | 24.38    | 1.4  | 24.0   | 33.4    | 42.6   |
| DH-2 #1<br>Control | 0-.75        | 8.6  | 10.8          | 2.2 | 7.0  | .84  | 0                              | 187.2                           | 1.70      | 0.53               | 0.3   | 18.63    | 1.2  | 48.2   | 31.6    | 20.2   |
| DH-2 #2            | .75-5        | 8.9  | 3.6           | 2.2 | 2.3  | .56  | 0                              | 69.6                            | .75       | .56                | 4.90  | 17.94    | 7.2  | 35.2   | 40.8    | 24.0   |
| DH-2 #3            | 5-9          | 8.5  | 4.2           | 2.2 | 1.4  | .68  | 31.88                          | 91.2                            | .45       | 5.70               | 10.00 | 18.75    | 16.0 | 36.0   | 39.2    | 24.8   |
| DH-2 #4            | 9-10         | 8.0  | 3.4           | 2.2 | 1.0  | .44  | 24.38                          | 79.2                            | .40       | 8.62               | 8.10  | 17.06    | 11.0 | --     | --      | --     |
| DH-2 a             | 27.1-48      | 8.3* | 12.0          | 3.2 | 21.0 | 3.80 | 0                              | 88.8                            | 1.20      | 1.67               | 1.00  | 17.56    | 2.1  | 10.0   | 55.0    | 35.0   |
| DH-2 b             | 58-75        | 8.3  | 30.0          | 3.8 | 1.2  | 3.52 | 0                              | 72.0                            | .92       | .99                | .50   | 11.56    | 3.5  | 21.0   | 53.4    | 25.6   |
| DH-2 c             | 75-129.5     | 8.4  | 21.0          | 3.1 | 1.6  | .52  | 0                              | 60.0                            | .50       | 1.28               | .50   | 5.63     | 6.9  | 65.0   | 24.4    | 10.6   |
| DH-2 d             | 129.5-146.9  | 8.6  | 22.2          | 2.4 | 1.3  | .32  | 5.63                           | 36.0                            | .20       | 1.02               | .50   | 3.56     | 6.7  | 79.0   | 12.6    | 8.4    |
| DH-2 e             | 166.5-177.3  | 8.3  | 40.8          | 2.9 | 3.6  | .96  | .38                            | 103.2                           | 1.10      | 1.05               | .60   | 11.19    | 3.3  | 47.2   | 32.6    | 20.2   |
| DH-2 f             | 177.3-204.5  | 8.4  | 36.6          | 5.6 | 1.2  | 11.8 | 0                              | 300.0                           | 1.40      | 1.45               | 1.80  | 47.25    | 1.9  | 17.8   | 28.2    | 54.0   |
| DH-2 g             | 204.5-217.5  | 8.8  | 30.6          | 2.2 | 1.7  | 3.60 | 0                              | 134.4                           | .55       | 1.15               | 4.60  | 15.88    | 5.6  | 22.4   | 53.4    | 24.2   |
| DH-2 h             | 217.5-252.1  | 9.5  | 13.8          | 2.5 | 1.0  | .32  | 0                              | 96.0                            | .25       | 1.00               | 7.00  | 16.25    | 7.5  | 69.0   | 13.2    | 17.8   |
| DH-2 i             | 252.1-263.8  | 8.9  | 19.2          | 4.0 | 1.4  | 1.08 | .38                            | 120.0                           | 1.10      | 1.36               | 5.40  | 11.75    | 6.1  | 53.8   | 28.2    | 18.0   |
| DH-2 j             | 263.8-271.4  | 9.1  | 9.6           | 3.4 | 0.5  | .36  | 0                              | 79.2                            | .20       | 1.27               | 4.70  | 9.38     | 7.4  | 71.6   | 14.6    | 13.8   |
| DH-2 k             | 271.4-303.4  | 8.4  | 21.0          | 2.4 | 1.8  | .36  | .38                            | 28.8                            | .45       | 1.62               | 2.50  | 2.69     | 11.0 | 71.2   | 19.0    | 9.8    |
| DH-3 #1            | 0-2          | 8.4  | 9.0           | 2.0 | 5.8  | .80  | 0                              | 117.6                           | 1.05      | .35                | .30   | 23.94    | .9   | 34.8   | 35.8    | 29.4   |
| DH-3 #2            | 2-5          | 8.6  | 4.6           | 1.9 | 3.7  | .56  | 1.88                           | 84.0                            | .55       | .39                | 2.0   | 13.75    | 4.0  | 33.2   | 38.6    | 28.2   |
| DH-3 #3            | 5-10         | 8.8  | 6.1           | 2.0 | 5.8  | .48  | 1.88                           | 93.6                            | .28       | .64                | 5.3   | 19.69    | 5.6  | 31.4   | 38.6    | 30.0   |
| DH-3 a             | 13.6-25.1    | 9.4  | 9.6           | 2.3 | 1.0  | 1.12 | 0                              | 165.6                           | .20       | 1.44               | 14.0  | 33.75    | 12.0 | 17.4   | 42.4    | 40.2   |
| DH-3 b             | 25.1-28.6    | 9.4  | 17.4          | 2.3 | 4.6  | .96  | 0                              | 117.6                           | .40       | 1.89               | 13.0  | 11.00    | 16.0 | 25.2   | 52.4    | 22.4   |





Table 1. (Continued).

| Site<br>Sample No. | Depth<br>ft. | pH   | DTPA Ext. ppm |     |      |       | NaHCO <sub>3</sub><br>P | NH <sub>4</sub> OAC<br>K | %    | mmhos/cm           |      | meq/100g |      | %    | %    | %    |
|--------------------|--------------|------|---------------|-----|------|-------|-------------------------|--------------------------|------|--------------------|------|----------|------|------|------|------|
|                    |              |      | Fe            | Zn  | Mn   | Cu    | ppm                     | ppm                      | O.M. | ECx10 <sup>3</sup> | SAR  | C.E.C.   | ESP  | S    | Si   | C    |
| DH-3 c             | 28.6-38.7    | 9.8  | 39.6          | 2.3 | 4.5  | 10.00 | 0                       | 187.2                    | .40  | 1.46               | 15.0 | 24.44    | 22.0 | 8.8  | 47.4 | 43.8 |
| DH-3 d             | 40.5-47.4    | 10.0 | 37.8          | 2.6 | 2.6  | 3.44  | 1.88                    | 252.0                    | .28  | 1.03               | 16.0 | 33.75    | 36.0 | 23.2 | 41.2 | 35.6 |
| DH-3 e             | 47.4-55.0    | 9.9  | 42.0          | 2.3 | 1.8  | 2.80  | .38                     | 194.4                    | .15  | 1.12               | 15.0 | 20.13    | 37.0 | 48.0 | 27.4 | 24.6 |
| DH-3 f             | 55.0-65.2    | 9.9  | 48.6          | 3.8 | 6.3  | 11.00 | 0                       | 204.0                    | .45  | 1.44               | 19.0 | 21.81    | 35.0 | 16.8 | 45.0 | 38.2 |
| DH-3 g             | 65.2-71.7    | 9.8  | 52.2          | 2.6 | 3.9  | 4.40  | 0                       | 117.6                    | .40  | 1.63               | 25.0 | 10.19    | 35.0 | 33.6 | 47.8 | 18.6 |
| DH-3 h             | 71.7-86.9    | 9.9  | 40.2          | 3.3 | 2.4  | .60   | 1.88                    | 127.2                    | .25  | 1.86               | 24.0 | 23.44    | 39.0 | 57.0 | 25.2 | 17.8 |
| DH-3 i             | 86.9-102.6   | 9.6  | 57.0          | 3.1 | 7.6  | 1.64  | 1.88                    | 105.6                    | 1.25 | 1.96               | 20.0 | 9.94     | 32.0 | 39.6 | 39.6 | 20.8 |
| DH-3 j             | 102.6-123.9  | 9.9  | 34.2          | 3.0 | 1.4  | 6.20  | 2.63                    | 196.8                    | .25  | 1.43               | 15.0 | 25.25    | 36.0 | 22.8 | 42.4 | 34.8 |
| DH-3 k             | 123.9-164.1  | 9.8  | 31.8          | 2.8 | 3.8  | 3.16  | 1.88                    | 96.0                     | .45  | 2.74               | 22.0 | 6.50     | 23.0 | 58.2 | 24.6 | 17.2 |
| DH-3 l             | 164.1-184.2  | 9.1  | 18.0          | 2.6 | 2.5  | .24   | 1.88                    | 24.0                     | .28  | 1.75               | 6.1  | 12.50    | 3.6  | 81.8 | 11.4 | 6.8  |
| DH-3 m             | 184.2-200.1  | 9.5  | 52.2          | 4.1 | 16.2 | 2.76  | 1.88                    | 144.0                    | 1.50 | 1.49               | 21.0 | 11.81    | 30.0 | 20.2 | 51.6 | 28.2 |
| DH-3 n             | 200.1-210.9  | 9.1  | 19.8          | 2.7 | 2.5  | .48   | 1.88                    | 40.8                     | .70  | 1.76               | 17.0 | 2.38     | 26.0 | 67.8 | 22.8 | 9.4  |
| DH-3 o             | 225.4-254.1  | 9.5  | 40.8          | 3.1 | 7.0  | 2.00  | 1.88                    | 81.6                     | .70  | 2.10               | 35.0 | 3.44     | 44.0 | 24.2 | 50.2 | 25.6 |
| DH-4 #1            | 0-1.8        | 8.6  | 28.2          | 2.2 | 13.8 | 1.04  | 0                       | 144.0                    | 1.10 | .62                | 2.4  | 29.88    | 2.5  | 27.4 | 28.4 | 44.2 |
| DH-4 #2            | 1.8-3        | 8.8  | 4.7           | 2.0 | 1.4  | .80   | 1.88                    | 79.2                     | .70  | 1.82               | 10.0 | 26.31    | 12.0 | 23.8 | 36.8 | 39.4 |
| DH-4 #3            | 3-5          | 8.3  | 5.0           | 2.1 | 1.8  | 1.04  | 7.13                    | 132.0                    | .45  | 6.29               | 12.0 | 26.25    | 12.0 | 26.0 | 36.6 | 37.4 |
| DH-4 #4            | 5-8.5        | 8.2  | 5.8           | 2.1 | 1.4  | .84   | 2.63                    | 156.0                    | .25  | 7.33               | 12.0 | 27.94    | 11.0 | 27.2 | 35.0 | 37.8 |
| DH-4 #5            | 8.5-13       | 8.5  | 5.2           | 2.1 | 1.3  | .80   | 1.83                    | 100.8                    | .25  | 3.17               | 14.0 | 17.00    | 16.0 | 22.0 | 48.4 | 29.6 |
| DH-4 a             | 13-22.6      | 9.4  | 10.2          | 2.0 | 1.8  | .56   | .38                     | 100.8                    | .20  | 1.04               | 11.0 | 15.69    | 6.1  | 24.8 | 47.4 | 27.8 |
| DH-4 b             | 22.6-36.5    | 9.9  | 37.8          | 2.2 | 4.3  | 5.20  | 1.88                    | 192.0                    | .20  | 1.02               | 14.0 | 22.25    | 27.0 | 16.0 | 45.4 | 38.6 |
| DH-4 c             | 36.5-47.2    | 9.8  | 40.2          | 4.7 | 15.2 | 6.60  | 1.88                    | 134.4                    | .35  | 1.71               | 25.0 | 8.63     | 36.0 | 21.0 | 49.8 | 29.2 |
| DH-4 d             | 47.2-57      | 9.9  | 51.6          | 5.6 | 2.6  | 16.40 | 1.88                    | 286.0                    | .45  | 2.21               | 27.0 | 35.06    | 39.0 | 18.2 | 36.6 | 45.2 |
| DH-4 e             | 57-66.3      | 10.0 | 36.0          | 2.2 | 5.0  | 3.16  | 1.88                    | 108.0                    | .20  | 1.28               | 20.0 | 13.44    | 40.0 | 31.0 | 44.2 | 24.8 |
| DH-4 f             | 66.3-69.5    | 9.9  | 44.4          | 5.9 | 6.0  | 11.0  | 1.88                    | 177.6                    | .50  | 1.40               | 19.0 | 22.50    | 37.0 | 27.6 | 24.6 | 47.8 |
| DH-4 g             | 69.5-74      | 9.9  | 42.0          | 3.9 | 5.84 | 6.80  | 2.63                    | 136.8                    | .61  | 1.44               | 22.0 | 13.44    | 37.0 | 9.2  | 61.4 | 29.4 |
| DH-4 h             | 74-82.1      | 10.0 | 39.0          | 3.0 | 2.7  | 10.00 | 7.13                    | 182.4                    | .20  | 1.39               | 21.0 | 21.25    | 42.0 | 32.6 | 33.6 | 33.8 |
| DH-4 i             | 84.8-92.5    | 10.0 | 43.2          | 5.0 | 3.7  | 14.40 | 2.63                    | 211.2                    | .28  | 1.38               | 19.0 | 25.00    | 39.0 | 12.0 | 39.2 | 48.8 |





Table 1. (Continued).

| Site<br>Sample No. | Depth<br>ft. | pH  | DTPA Ext. ppm |     |      |      | NaHCO <sub>3</sub> | NH <sub>4</sub> OAC | %    | mmhos/cm           | SAR  | meq/100g |      | ESP  | %    | %    | % |
|--------------------|--------------|-----|---------------|-----|------|------|--------------------|---------------------|------|--------------------|------|----------|------|------|------|------|---|
|                    |              |     | Fe            | Zn  | Mn   | Cu   | P                  | K                   |      |                    |      | C.E.C.   | S    |      |      |      |   |
|                    |              |     |               |     |      |      | ppm                | ppm                 | O.M. | ECx10 <sup>3</sup> |      |          |      |      |      |      |   |
| DH-4 j             | 95.5-111.3   | 9.7 | 58.2          | 3.1 | 3.8  | 8.00 | 7.13               | 163.2               | .40  | 1.50               | 25.0 | 15.94    | 36.0 | 11.4 | 55.8 | 32.8 |   |
| DH-4 k             | 111.3-120.4  | 9.9 | 52.8          | 3.5 | 19.0 | 3.16 | 10.13              | 139.2               | 1.80 | 1.64               | 24.0 | 13.75    | 34.0 | 11.8 | 59.8 | 28.4 |   |
| DH-4 l             | 120.4-192.0  | 9.9 | 18.6          | 2.6 | 2.6  | .40  | 10.13              | 57.6                | .20  | 1.53               | 21.0 | 6.31     | 39.0 | 71.8 | 18.4 | 9.8  |   |
| DH-4 m             | 192.0-223.2  | 9.8 | 58.8          | 5.1 | 3.0  | 8.40 | 7.63               | 218.4               | 1.10 | 1.70               | 23.0 | 28.75    | 38.0 | 15.2 | 42.6 | 42.2 |   |

\*pH - 1:5 solution



Table 2. Postharvest soil analysis on selected samples.

| Cluster | Sample No.         | Plant Available |          | DTPA Ext. ppm |      |      |      |      |     |     | pH  | mmhos/cm<br>ECx10 <sup>3</sup> | C.E.C. | ESP  | SAR  | ppm |       |
|---------|--------------------|-----------------|----------|---------------|------|------|------|------|-----|-----|-----|--------------------------------|--------|------|------|-----|-------|
|         |                    | ppm<br>P        | ppm<br>K | Zn            | Fe   | Mn   | Cu   | Cd   | Ni  | Pb  |     |                                |        |      |      | B   | Mo    |
| 1       | DH-1 #1            | 22              | 140      | 0.4           | 6.2  | 7.5  | 0.5  | <0.1 | 0.6 | 0.5 | 7.4 | 2.0                            | 15.7   | <1.0 | 1.6  | 0.7 | <0.05 |
|         | DH-4 #1            | 13              | 146      | 0.3           | 7.7  | 8.5  | 1.0  | <0.1 | 0.5 | 1.0 | 7.6 | 2.5                            | 29.8   | 1.7  | 2.9  | 0.7 | <0.05 |
|         | DH-2 #1<br>Control | 28              | 200      | 0.4           | 12.7 | 37.4 | 0.8  | <0.1 | 1.1 | 0.7 | 6.7 | 2.8                            | 16.7   | <1.0 | 1.1  | 0.7 | <0.05 |
| 2       | DH-1 #3            | 32              | 140      | 0.1           | 2.0  | 8.3  | 0.6  | <0.1 | 0.4 | 0.6 | 7.8 | 3.5                            | 17.3   | 4.0  | 5.8  | 1.5 | 0.35  |
|         | DH-4 #5            | 5               | 90       | 0.3           | 4.8  | 3.9  | 0.8  | <0.1 | 0.2 | 1.3 | 7.5 | 5.1                            | 15.0   | 12.7 | 13.2 | 0.3 | 0.05  |
| 3       | DH-4 #4            | 1               | 167      | 0.4           | 5.9  | 4.9  | 0.9  | <0.1 | 0.3 | 0.7 | 7.6 | 10.2                           | 26.2   | 11.5 | 13.0 | 0.4 | <0.05 |
| 5       | DH-2h              | 3               | 108      | 2.4           | 12.1 | 5.3  | 0.8  | <0.1 | 0.3 | 1.7 | 7.8 | 3.6                            | 13.2   | 4.5  | 6.3  | 0.4 | <0.05 |
|         | DH-3l              | 11              | 38       | 1.8           | 14.2 | 4.5  | 0.3  | <0.1 | 0.2 | 0.5 | 7.2 | 4.8                            | 1.4    | 7.1  | 4.0  | 0.9 | <0.05 |
| 6       | DH-3g              | 25              | 128      | 2.2           | 49.8 | 9.1  | 4.4  | <0.1 | 0.1 | 2.4 | 8.1 | 6.0                            | 13.7   | 31.4 | 31.3 | 0.8 | 0.06  |
|         | DH-4i              | 8               | 241      | 9.8           | 38.0 | 8.5  | 10.0 | <0.1 | 0.4 | 6.5 | 8.1 | 5.8                            | 25.4   | 30.3 | 36.3 | 1.0 | 0.15  |
| 7       | DH-3h              | 16              | 113      | 3.0           | 38.0 | 10.1 | 0.9  | <0.1 | 0.2 | 1.9 | 7.9 | 6.0                            | 19.6   | 27.0 | 31.9 | 0.8 | 0.13  |
| 8       | DH-4k              | 11              | 162      | 4.3           | 45.0 | 52.2 | 7.0  | <0.1 | 0.9 | 1.7 | 7.9 | 7.3                            | 15.4   | 26.6 | 27.6 | 0.9 | 0.34  |

As and Se fell below the detection limit of <0.5 ppm.





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